WEDNESDAY, MARCH 28TH, 1906.

The Thirty-first Annual General Meeting of the Society was held in the Linnean Hall, 23 Ithaca Road, Elizabeth Bay, on Wednesday evening, March 28th, 1906.

Mr. T. Steel, F.C.S., F.L.S., President, in the Chair.

The Minutes of the preceding Annual General Meeting (March 29th, 1905) were read and confirmed.

The President delivered the Annual Address.

PRESIDENTIAL ADDRESS.

The past Session has been marked, as usual, by an amount of scientific activity which affords grounds for satisfaction. Thirty-two papers were read, and opportunities for the discussion of the subjects treated of were offered, at the Meetings held during the year. The majority of the papers have been published and distributed, together with a "Check-List of the Sub-family *Carabinæ*," which was issued as a Supplement to Part i., free of cost to the Society. The remainder, comprising the seven papers read at the concluding Meeting of the Session, have been printed off and will be issued in the last part of the Proceedings for 1905, which is now almost ready for publication. Last year's volume will, in respect of size, be somewhat behind its immediate predecessors, but in this connection it must be remembered that early in the Session a new issue of the Rules, &c., was printed, and also that the Session opened with a debit balance of £63, which necessitated some curtailment of the Society's publishing energy. I am very glad to say that the Hon. Treasurer will presently be able to announce not only that the debit balance has been liquidated, but also that the Society begins the new financial year with a balance to the good. This is a matter for satisfaction, but it has mainly been brought about by constant watchfulness on the part of the Council to in every possible way keep down the cost of publication. The necessity for the utmost care in this matter will be apparent when I point out that a recent re-investment of £2,000 of the Society's capital had to be made at the rate of $3\frac{1}{2}\%$ interest, the lowest which we have ever received. This item alone means a reduction of £10 in the Society's income, which, as you know, has already been affected by the shrinkage in the interest-bearing value of money to an extent which was never anticipated by our revered patron, Sir William Macleay.

For the reasons mentioned the Council found it necessary to postpone temporarily the publication of the Macleay Fellow's first paper, on account of the length of the MS., and the numerous illustrations required. A beginning will, however, be made with this paper at the April Meeting.

In addition to the full number of ordinary meetings, a special meeting was held in January last, at which Dr. W. A. Roth, Chief Protector of Aborigines, Queensland, gave a most luminous and instructive lecture on the Aborigines of North Queensland, illustrated by a quite unique collection of lantern slides. It is a pleasure to place on record our very high appreciation of the work which is being carried out by Dr. Roth, in the fulfilment of his important duties in furthering the best interests of the Aborigines, and in his extremely valuable ethnological observations.

Nine Ordinary Members were elected during the year, and two resignations were received, a nett increase of seven. As the names of twenty-five non-effective Members were removed from the Roll just before the issue of the new edition of the Rules and List, the number of Members remains at about 120.

The Society has to regret the loss of the oldest surviving Honorary Member, Captain F. W. Hutton, F.R.S., Curator of the Canterbury Museum, Christchurch, New Zealand, whose connection with the Society dated from 28th October, 1878. Captain

Hutton retired from the army in 1866, after seeing active service in the Crimea, in China, and in India during the Mutiny. Upon his retirement he emigrated to New Zealand, and had nearly completed forty years of almost uninterrupted scientific and educational work in that Colony. Captain Hutton died at sea, while on the return voyage from a holiday trip to Europe, on 27th October, 1905, within a few days of the completion of his 69th year. A brief biographical sketch of Captain Hutton will be found in 'Nature' for 9th Nov., 1905 (p.32). A less recent, but much longer account of his life and work, with a portrait, was published in the 'New Zealand Journal of Science' (Vol.ii., No.7, p.301). At the time of his death Captain Hutton was President of the New Zealand Institute. His New Zealand colleagues have already taken steps to inaugurate a Hutton Memorial Research Fund. Captain Hutton contributed several papers to our Proceedings. He will be affectionately remembered by Australian scientists who have had frequent opportunities of meeting him on his periodical visits, particularly in connection with the meetings of the Australasian Association for the Advancement of Science.

Mr. H. I. Jensen, B.Sc., has been reappointed to a Linnean Macleay Fellowship; but the Council did not see its way to make any new appointments of Macleay Fellows last year. The standard which the Council has fixed is a high one, and it is considered desirable that the most ample proof of ability and of sufficient preliminary experience should be asked from Candidates for so important appointments.

The present Macleay Fellow, Mr. Jensen, during the past year has been occupied with a research on the distribution, nature and sequence of volcanic rocks, particularly trachytes, in certain districts. In April, 1905, he went to Queensland, where he spent three months investigating in the field and mapping the volcanic masses of parts of the East Moreton and Wide Bay districts. He found that rocks of the Glass House Mountain type recur about twenty miles north of the Glass House Mountains, in the Maroochy River district, near Yandina, after a considerable break covered with basalt flows. Here these rocks are associated with rhyolites, dacites, andesites and basalts. Necks and plugs, forming gigantic monoliths (Coolum Mt., Mt. Cooran, Mt. Cooroora, Mt. Eerwah, &c.), and belonging to this group, were found at intervals between the coast on the east and the Blackall Range on the west, the Maroochy River on the south, and Kin-Kin Creek on the north.

In the D'Aguilar Range he discovered on and around Mount Mee an interesting series of metamorphic rocks, including glaucophane and anthophyllite schists, rutile and cyanite granulites, and allied rare rocks. Further westward, on the Stanley River at Neurum, he found numerous rhyolite and pitchstone peaks (Mt. Archer, &c.). The metamorphic rocks of the D'Aguilar Range were found to be traversed by dykes of sölvsbergite and keratophyre. Many interesting physiographical problems were studied, and the observations made upon raised beaches, the enormous sand hills along the coast at Noosa River, and the great Coolum swamps and coastal lakes at Noosa should prove of interest. An important fact noticed was the occurrence of great igneous intrusions of porphyrite at Pt. Arkwright, and of true quartz diorite at Noosa Head into the Triassic sandstones.

On his return to Sydney Mr. Jensen sectioned and examined under the microscope the rocks collected upon the excursion, and spent some time writing up his results, making maps, and drawing ideal sections of the district.

In October he again left Sydney, going this time to the Warrumbungle Mts., where he made a preliminary trip through the district, going completely round the mountain mass, and making incursions to the centre of the group from Coonabarabran, Tannabar, Wargon Creek, Tooraweanah and Bugaldi. He was able in this way to construct a rough geological map of the district, which will serve as an excellent basis for further work this year. The nature of the volcanic rocks which range from trachyrhyolite to basalt, and their relations to the Triassic and Permo-Carboniferous sedimentary rocks of the district, were investigated as closely as time would permit. A new diatomaceous earth deposit was examined at Bugaldi, and was seen to be overlying as well as capped by basalt.

The most interesting results of the trip were, however, the physiographical. The volcanic masses are, in Mr. Jensen's opinion, the remains of an old dome-shaped lava plain, to which the term "conoplain" may be extended to apply. The dissection of this plain has taken place mainly through "arid agencies." We have then, in this district, excellent examples of "arid erosion."

Before returning to Sydney Mr. Jensen visited the Nandhewar Mts., which, both in petrological character and in topography, bear close resemblance to the Warrumbungles, and also give definite evidence of the arid cycle type of erosion.

On his return from this expedition in December, the Macleay Fellow took up the chemical investigation of the Glass House Mountain rocks, and has since made twelve complete rock analyses and several silica estimations, which are bringing to light important facts. Many of the rocks hitherto described as "orthophyric trachytes" are, in reality, too acidic to bear the name of trachyte. They belong to the comendites and pantellarites. The highly sodic nature of all the rocks of the district was chemically verified, and the close relationship of the Pt. Arkwright porphyrite with the Noosa Head quartz diorite was verified analytically as well as mineralogically.

During the past year, the Macleay Bacteriologist continued certain work upon the bacterial origin of the vegetable gums. The gummy exudate issuing from a species of Hakea was shown to possess rather indefinite characters which militated against tracing it to any of the bacteria that were found in the tissues of the plant. The investigation, however, went far to prepare the way for another research. While it is evident that a gum or mucilage which may exude from a plant is abnormal and may be the result of the work of micro-organisms, we are not so ready to believe that a mucilage which does not exude and which is a normal constituent of a plant, can have other than a vegetable origin. Yet it has not been shown that a regulated formation of slime, gum or mucilage by bacteria is otherwise than an advantage to the plant. It may be that it is only an abnormal production that is injurious and makes itself evident as a gum—or slime—flux. An investigation of the gum of Linseed mucilage and of the gums produced by bacteria isolated from the tissues of the plant, showed that one or two of the microbes formed gum so similar to Linseed gum as to point to its having been originally formed by the bacteria and subsequently altered by the plant to mucilage. In reviewing the work that has been done in the Society's laboratory, upon the production of gum, it will be noticed that the majority of the bacteria are very closely allied; the only differences being in the nature of the gums and the cultural characters which are influenced by the gums. It has been found that their typical faculty alters under certain circumstances, and it is, therefore, probable that the group originally consisted or consists of one type-species, the physiological activity of which has been or can be modified by a host-plant. Bacteria are to a certain extent classified by their action while growing upon gelatin media, which they either do or do not liquefy. A microbe which brings about a hardening of the medium is a novelty, and such a microbe has been described by our bacteriologist. Another curiosity which he brought forward was a bacterium which had attached to it capsular structures like lateral wings.

In another branch of bacteriology, Dr. Greig-Smith has indicated that the immunity which we all possess against the multiplication of the putrefactive bacteria may have its origin in the slow but continued passage of these bacteria across the wall of the intestinal tract. The result is as if we were being continuously vaccinated with these bacteria. Within the tissues and vessels of the immune animal, bacteria are destroyed either in the fluids or within the phagocytes. The mobile leucocytes can readily ingest harmless bacteria, but the same facility is not exhibited towards those which are virulent. From a consideration of the physical relation between a microbe and a mobile phagocyte, it appeared probable that if the former were covered with a substance positively chemotactic towards the latter, it would be englobed and in all probability subsequently dissolved. Such a covering occurs in the first phase of agglutination. This matter was investigated and it was found, after the destruction of certain substances which might interfere with the main issue, that agglutinated bacteria were phagocytosed. It was also found that bacteria which had been agglutinated by certain chemical substances, instead of by active sera, were refused by the phagocytes. The property of immune serum to induce the phagocytosis of bacteria has been previously noted and recently the active substance has been called opsonin. The similar behaviour of agglutinin suggested that they might be closely related. The subject was experimentally examined and it was shown that the opsonins and the agglutinins agreed in so many points as to leave little doubt that opsonisation is the first phase of agglutination.

Two students received full courses of instruction in the Society's laboratory during the year.

It is with special pleasure that I allude to the receipt by Professor Haswell of a grant of £125 from the Royal Society of London for the purpose of carrying on dredging operations in the Tasman Sea. Mr. Hedley is co-operating with Professor Haswell in this important scientific undertaking. The military authorities have granted the use of s.s. "Miner" for the purpose. Messrs. Bullivant have kindly undertaken to supply the necessary 3,000 fathoms of steel wire rope, with special non-purchase reel, at cost price, and, although this will absorb the bulk of the grant, it is confidently anticipated that the results obtained will be such as will lead to further aid being granted. It is intended to investigate the life of the Tasman Sea at depths of about 2,000 fathoms, dredges of special novel construction being used.

Another matter of interest which I would just like to mention is the recent examination of the Blue Lake, Mount Kosciusko, by means of a little dredge worked in the most ingenious manner from a specially built coracle by Professor David, Mr. Hedley, and colleagues. The detailed results are not yet available, but

Professor David informs me that the general character of the organisms secured is distinctly Tasmanian.

It is with pleasure and satisfaction that I have to announce that the Council has arranged to give our respected Secretary, Mr. Fletcher, a well deserved holiday. After his record of some 20 years of continuous, faithful and unremitting service, without anything but the briefest of holidays from to time, during which long period Mr. Fletcher has been absent from only two monthly meetings, and that through sickness, I feel sure that the Council's action will meet with the cordial approval of the Members, and in your name I desire to assure Mr. Fletcher of the high esteem in which he is held by Council and Members alike. Mr. Fletcher has decided to take his leave in instalments, and goes on a visit to the north in a few weeks' time. During his absence it has been arranged that the secretarial work will be carried on by Dr. Greig-Smith.

Dr. Greig-Smith having expressed a desire to visit Europe in order to bring himself into touch with the present condition of bacteriological science, the advance in which is so extremely rapid, the Council has granted him the requisite leave, and he intends going towards the end of the present year, and will be absent for about nine months.

Since the arrangements for the Annual Elections were made by the Council, in accordance with the provisions of the Rules, and too late for consideration at this Meeting, the Council received Mr. Edgar R. Waite's resignation as a Member of Council, in consequence of his contemplated removal to New Zealand, to take up the position of Curator of the Christchurch Museum, in succession to the late Captain Hutton. The extraordinary vacancy so caused will be filled by the Council at an early date, in accordance with the powers conferred by the Act of Incorporation. In the meantime the Council has placed on record an expression of its regret at Mr. Waite's departure from Australia. And I feel sure that in addition to the congratulations of the Council upon his appointment, and its hearty good wishes for a most prosperous career in New Zealand, I may cordially offer those of the Society at large.

The necessity for taking effectual steps to combat the continued spread of the rabbit in Australia is one which is patent to all. A new phase of the problem involved in the destruction of this animal has been recently presented to us, and it takes a form which should not fail to arouse the watchfulness and attention of Australian Scientific Societies. Last December the Minister for Lands approved of experiments being carried out with a disease the use of which was proposed by Dr. Danysz of Paris, provided the Government were not asked to bear the cost. The management of the scheme has been committed to the Pastures Board Council of Advice, which has received sufficient monetary support from pastoralists and stockowners towards the £15,000 required, to enable the negotiations with Dr. Danysz to take practical shape. Broughton Island, situated 31 miles north of Newcastle, and having an area of about 1000 acres, has been selected as the locality for the experiment, and a supply of rabbits from the mainland has already been turned loose thereon. If the negotiations with Dr. Danysz do not fall through it seems probable that practical work will be entered upon at no very distant date. The preliminary arrangements are evoking numerous expressions of public opinion which vary according to individual standpoint, but practically only two views are held. One side appears to think and talk as lightly of the introduction of a foreign pathogenic microbe of unknown potency under changed conditions, as did those primarily responsible for the introduction of the rabbit itself as well as of the fox, sparrow, starling and other pests, of any possible danger to the country in the course they were taking. The other side, profiting by past experience, desires to consider probable developments before the country is committed to a step which may have results of the gravest character.

The promotors of the scheme are sanguine through the operation of this disease, if not to exterminate the rabbit, to at any rate hold it materially in check. Taking past experience as a guide, it does seem desirable to be better assured than we now are that the disease in question will confine itself to the rabbit. We have a parallel case in the plague bacillus as affecting man and the rat in common, the latter being, like the rabbit, a rodent. There is also the question whether the means proposed are likely to have the desired effect. While thousands of rats have died through the operation of plague, in no case do we hear that there has been extermination. The disease only kills those individuals which are susceptible, leaving the others which are sufficiently resistant to recover or to escape infection altogether; and when the epidemic has, as it is termed, "run its course," the balance of population is quickly restored from the surviving immune stock. There appears to be no reason to expect anything else with rabbits; it seems inevitable that there will be no extermination, but merely a killing off of susceptible individuals, leaving the others to propagate, while we have the serious risk that the disease will not confine itself to the rabbit, for there is no foretelling in what direction it may develop or what other animals may be attacked when the bacillus has become acclimatised. That some microbic diseases are profoundly altered in their nature by passing through one or more hosts of different species, is now well established, and there is no guarantee that this rabbit disease—which we are informed is not directly communicable to man—may not become so after affecting another animal, which may, perhaps, be reptile, mammal or bird. The same danger applies to domestic animals and stock, which may quite possibly become secondary hosts for the bacillus. Bacteriology has taught us in how remarkable a manner many bacilli are able to adapt themselves to new conditions, and how readily and unexpectedly they will become acclimatised when their surroundings are altered.

There appears to be a good deal of mystery about the precise nature of the disease which it is proposed to utilise, and different statements on this point have found currency. As bearing on the whole question, it may not be out of place to mention a fact which does not appear to be very well known in Australia, that in certain parts of Europe a disease known as rabbit syphilis is prevalent amongst these creatures, and though, so far as is known, it is not communicable to man, its existence is naturally viewed with repugnance by the people. In Westphalia, for instance, although the disease is very common, the animals are not exterminated thereby; there are always plenty of healthy as well as diseased rabbits to be seen, the fact being that the balance of numbers is maintained by the healthy stock. Where this disease occurs rabbits are never used as human food.

Considering the matter broadly, it is, to say the least, highly undesirable that disease should be wilfully communicated to any animal to be broadcasted over the land. It is quite certain that the rabbit has come to stay; it will never be exterminated: but it certainly can and ought to be kept in bounds by means other than the introduction of disease.

A matter which calls for the active attention of all lovers of Nature in Australia is the preservation of the native fauna. The indiscriminate and wanton destruction of birds and mammals which is now going on over the length and breadth of the land is appalling. It is bad enough when introduced pests like the fox are threatening the absolute extinction of such characteristic birds as the lyre-bird, but when to this is added the meaningless slaughter, for the mere sake of killing, of anything, be it bird or mammal, which is capable of being shot, by the so-called sportsman, it is surely time to call a halt. A member of this Society put the case excellently, when in speaking of the purposeless killing of the native bear, he said—"A man who can go and shoot bears for the fun of it should feel at home with a gun among a flock of sheep."* To this must be added the inadvertent destruction of native animals through poison laid for rabbits. By the careless use of poison, either in baits or in water, enormous numbers of our native mammals and birds are being killed, and as the latter include some of the most valuable insectivorous species, their destruction must have its inevitable result in the undue multiplication of noxious insects which will exact a heavy

* Mr. A. H. S. Lucas. Handbook of Melbourne: Aust. Assoc. Adv. Science, 1890, p.61.

toll from the crops of the agriculturist. As a community we seem strangely slow to learn by experience. The introduction of sheep and cattle, to say nothing of rabbits, has been a profound factor in altering the balance of Nature in Australia, and when in addition useful and harmless creatures alike are persecuted out of existence in a spirit of mere idle brutality, it is little to be wondered at that nature retaliates in no uncertain way.

OCEANIC PHYSICS.

Taking advantage of the generous latitude in the choice of a subject for his Annual Address which in the past has been accorded to your President, I desire to ask your attention to-night to one to which I have devoted some study during the last few years—that of Oceanic Physics.

The study of the features of our ocean as they present themselves to the physicist is very necessary if we are to clearly understand the problems with which we, as naturalists, are continually faced in the course of our observations on the sea and its living denizens. For a proper comprehension of the more important phenomena pertaining to our ocean we must take a great step backwards and draw an imaginary picture of what were the physical conditions of the cosmos at extremely remote periods in geological time. The exigencies of our subject take us far back down the ages to the very genesis of the world, and knowledge placed at our disposal by the researches of modern investigators renders it a comparatively simple matter to picture to ourselves the conditions which must have prevailed when the sea first began to come into existence. The nebular hypothesis provides that at one stage in the history of the solar system, of which our world is so small a unit, the matter of which it is composed was in an extremely finely divided or nebulous condition, and occupying a very great volume in infinite space. At this time, what is now our solar system probably formed one amongst the many others which then, as now, existed in all stages of metamorphosis, floating in the limitless regions of stellar space :—

> "Where never creeps a cloud, nor moves a wind,
> Nor ever falls the least white star of snow,
> Nor ever lowest roll of thunder moans,
> Nor sound of human sorrow mounts, to mar
> Their sacred everlasting calm."

Speculation and theory, founded on the investigations of specialists in mathematics, physics and chemistry, are now carried much farther back than this stage, far back even to the condition before matter as such existed, when that which we now know as matter was in the form to which the name of protyle has been aptly applied by Sir William Crookes, and to which form, curiously enough, recent researches on radium and its allies are leading us to believe matter is again returning. This is a very wonderful thought, and Sir William Crookes thoroughly grasped its immense significance when, in speaking of radium, he recently said: "Matter will sooner or later be dissolved into a 'formless mist,' and the hour-hand of eternity will have completed one revolution."

With this period in the history of the earth we will not deal to-night, but, starting at the nebular stage, we will commence our brief retrospect. Let us imagine the material of which our solar system is composed, in a state of disintegration, probably dissociated into its constituent elements, and occupying a vast portion of space having a diameter greater than the orbit of the most distant planet, so much attenuated, indeed, as to be in a condition resembling that of the gas inside an exhausted vacuum tube. Matter in this condition would still obey the ordinary physical laws, and so be subject to the action of gravity. Such being the state of affairs, motion towards the centre would begin. The individual atoms or molecules would commence to move with a slow but constantly accelerating motion, which might be so slight as only to amount in the first instance to a few inches, or a few fractions of an inch, in many years' time, but with all eternity in which to act this would be a matter of no moment. The motion so begun would, under the well understood action of gravity, be constantly accelerated, until, with the lapse of time, material concentration had taken place.

As a result of this falling together, and apart altogether from the enormous energy set free through the chemical reaction of elements one with another, vast quantities of heat would be generated. Lord Kelvin has calculated that the heat liberated by the condensation of matter in this manner would be amply sufficient to render the whole mass glowing hot, and would, in the case of the solar system, readily account for the present heated condition of the sun. The incandescent mass would surge and boil out again, and probably in so doing become separated into numerous portions, and these having in this manner acquired initial proper motion, would form the nucleus of a solar system. By slow degrees the vapours forming one of these masses, which we will suppose to be the infant earth, would cool down sufficiently to form a molten mass, in which only the more intractable substances would be in a fixed condition, all the others constituting a glowing atmosphere such as at the present time surrounds the sun. Water would either be dissociated into its elements or later on would exist as steam. As the process of cooling went on the more readily condensed bodies would fall as rain—iron, for example, as glowing drops of oxide—into a molten sea surrounding the young world. Probably substances like gold, platinum, silica, etc., having the highest melting points, would be the first to condense, thus forming a heavy nucleus, and it is possible that the rare heavy metals named, with many others now obtainable only in small amounts scattered through the upper crust of the earth, are but the froth and splashes from immense central stores which formed the first core of the youthful earth. It has been found that on an average the increase in temperature of the earth's crust downwards for such depths as we have been able to examine, is 1° F. for about 51 feet of descent. The greatest depth, however, to which it has been found possible to penetrate with the boring appliances at our disposal, is a very minute fraction of the distance to the earth's centre. In the consideration of the condition of matter at great depths beneath the surface it is frequently assumed that the observed rate continues, or even increases, and that, consequently, extremely high temperatures exist towards the centre. The earth's radius is roughly about 21,000,000 feet, and if the above rate of increase were maintained throughout we should have at the centre a temperature of about 420,000° F., while some writers have not hesitated to estimate the probable temperature at as high as 1,000,000° F. Matter of any kind with which we are acquainted would, at such temperatures, be much above its critical point, *i.e.*, the temperature at which condensation is possible, and hence would be in a state of vapour. It has been considered that the enormous pressure to which everything at such depths is subjected would render this gaseous matter more rigid than solid steel, the gaseous molecules being in a state which might be expressed as one of "gaseous solidity."* A careful review of the evidence, and particularly of the masterly mathematical examination of the subject by Lord Kelvin,† leads me to the conviction that reasoning based on the assumption of a uniform increase in temperature downwards is quite fallacious, and that a maximum is reached at a comparatively moderate depth. The conclusion arrived at by Lord Kelvin is that the observed increase in temperature downwards is not maintained, but falls off at such a rate that at a depth of about 600,000 feet the rate of augmentation has fallen to only one-tenth of a degree F. per 51 feet, while at about 800,000 feet it has practically reached zero with a temperature of about 7,000° F., which continues to the centre.

As the process of cooling proceeded the growing earth would become denser and denser until solidification ensued, and the more

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* Nature, 13th April, 1905 (Vol. 71, p. 559) and 11th May, 1905 (Vol. 72, p. 30).

† Thomson and Tait, Natural Philosophy, Vol. i., Appendix D; Rep. British Assoc. Adv. Science, 1876, Reports, p. 204.

volatile substances would commence to fall as rain. In this way, prior to the condensation of water, such bodies as salt would fall like snow, or perhaps as brine, and afterwards, when the water condensed, would be dissolved, and so the primitive ocean would be saline. The first sea would be a boiling one, the water being continually vapourised and falling again as hot rain. Obviously all the saline matter in the earth would not be subject to the solvent action of the hot primitive ocean, as large quantities would be combined with and mixed up with the other solid substances.

We now have our young world with its hot ocean, probably salter than it is at present, because vast quantities of water which are now contained in the sea would then be floating as a dense cloud around the earth. As the process of cooling and condensation went on the ocean would become less saline and cooler, and so better fitted for the establishment of living organisms. We have evidence that the earliest forms of living things originated in the sea, and from thence by slow degrees spread to the dry land.

The ancients considered the world to be a flat disc-shaped body, surrounded by a river, which they named Oceanus, hence our present name. Quite three-fourths of the earth's surface is covered by the sea, this being equal to an area of about 140,000,000 square miles. The earth is, of course, not truly spherical in shape, but is flattened at the poles and bulging at the equator, though most people have a greatly exaggerated idea of the extent of this polar flattening. In reality it is not nearly as great in proportion as that of an orange, to which the earth is so often likened. The longer or equatorial diameter is about 7,927 miles, and the shorter or polar 7,900, a difference of only 27 miles, which is equal to 1 in 300, or for a globe 25 feet in diameter, a flattening of half an inch at each pole, an amount quite imperceptible to the eye.

The saline matter in the ocean is continually being added to by that washed out of the earth by rain and carried to the sea by rivers and percolation. In this connection a recently published analysis by Mr. A. G. Levy of water from the Simplon Tunnel is of interest.* This water is considered by M. Bertram Blount to be entirely plutonic in its origin, and, while it contains considerable proportions of calcium and magnesium sulphates, is remarkable in being quite free from chlorides. The chlorides are amongst the most volatile of the so-called fixed salts, and hence would be the last to condense during the genesis of the earth. Professor Joly has based calculations regarding the age of the earth upon the estimated rate at which chlorides are now being carried by water from the land to the ocean; but consideration of the probabilities as to the condensation of such substances during the earlier part of the earth's history and the consequent enormous initial saltness of the sea, indicates how very unsafe are the conclusions arrived at from evidence of the kind.†

If the process of land denudation now going on lasts for a sufficiently long period the time will come when the whole surface of the globe will be covered with water, and, if the solid matter is uniformly spread over the ocean floor, the universal ocean will have a depth of about 1,700 fathoms. The mean present depth of the sea is about 2,500 fathoms, or almost three miles, so that the mass of land above sea level is sufficient in bulk, if thus spread out, to reduce the depth over the whole surface by only some 800 fathoms. As a matter of fact the submerged valleys beneath the surface of the sea are sufficient in size to contain quite three times as much bulk as there is of dry land above sea level.

The greatest known depth is about 27,700 feet, or $5\frac{1}{4}$ miles. At such enormous depths as this the pressure of the water is very great. A column of fresh water one mile in depth exerts a pressure of 2,288 lbs. per square inch, whilst the same depth of the heavier sea water has a pressure of 2,347 lbs. For a depth then of $5\frac{1}{4}$ miles we have the prodigious pressure of 12,320 lbs., or $5\frac{1}{4}$ tons per square inch.

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* The Analyst, xxx., 367.

† See Prof. G. H. Darwin's Presidential Address to the British Association. Nature, August 31st, 1905; Chemical News, lxxxix. 13 (1904).

Ordinary light can only penetrate to a comparatively small depth, for at 200 fathoms practically no action on a photographic plate can be detected. At depths greater than 2,000 fathoms the water is never more than a very few degrees above freezing point and is practically uniform in temperature over the bulk of the ocean floor. It thus comes about that the same forms of life are dredged from great depths everywhere, and there is absolutely no barrier at such depths to the uniform migration of animals in all directions.

Of the superficial characters of the ocean, waves are probably the first feature which would attract the attention of an observer. In ordinary wave-motion there is very little drift or translatory movement of the water; the water remains practically in the same spot: it is the motion only which travels. A wave is, in fact, the passage of motion from position to position. The water is first heaped up, forming the crest, and then depressed, forming the trough, the mass of water which forms a given crest sinking, and, as it were, forcing up the mass in front to form the next crest. From this it is obvious that the motion exists equally beneath as above the surface, and the consequent friction is the principal cause of the rapid flattening of the water which ensues when the wind ceases. The greatest height attained by ocean waves does not, probably, often exceed 45 feet, but to reach such a height the essential conditions are a sufficient stretch of ocean and a great enough velocity of wind sustained for a long enough period. There is a relationship between the size of waves and the velocity of the wind, which may be expressed in the terms that the velocity of the wind in miles per hour is roughly twice that of the height of the waves in feet. Thus, suppose the wind to be blowing over a stretch of ocean of sufficient breadth at the rate of twenty-five miles per hour, it is able to raise waves having a height of about 12½ feet. The waves are prevented from attaining a greater height because they have not a sufficient thickness to permit of their withstanding the increased total wind pressure which they would then have to bear, and, accordingly, the wind would merely tend to depress them. A given wave is, in fact, in equilibrium with the wind when once the height corresponding with the wind velocity is reached. It is a matter of common observation that a certain breadth of ocean is required before the wind can raise waves corresponding in height to its velocity; this is technically known as "fetch." A steady wave has a maximum length—distance from crest to crest—of somewhere about twenty times its own height, and, in a general

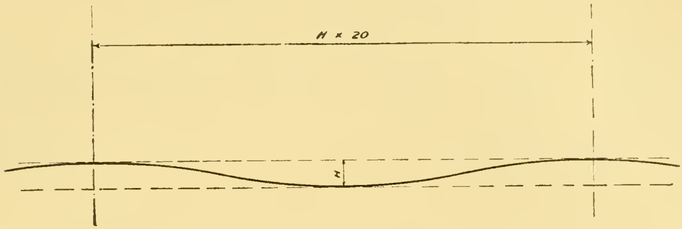

Diagram showing the relation of Wave-height to Wave-length.

way, the "fetch" necessary for the production of a normal wave is about 2,000 times its length. Taking the case before cited of a wave $12\frac{1}{2}$ feet high, which, we have seen, corresponds to a wind velocity of 25 miles per hour :—$12\frac{1}{2} \times 20$ gives 250 feet as the normal length of such a wave, and $250 \times 2{,}000 = 500{,}000$ feet, or nearly 95 miles. We see then that a wind blowing at the rate of 25 miles per hour, requires a stretch of some 95 miles of ocean in which to raise $12\frac{1}{2}$ feet waves, the normal height for this wind speed. Higher wind velocities require correspondingly longer "fetches" of ocean surface in order to produce their maximum wave effect. When the wind dies away the waves tend to flatten down and form ocean swell, which really consists of waves of comparatively small height, but considerable wave length. With such a swell already in existence a fresh storm travelling in the same direction will quickly raise waves of the maximum height. Further, the rate at which wave motion travels on water varies with the other properties of the wave. Another important property of any wave is its frequency or number of recurrences in a unit of time. This is a product of $\frac{\text{velocity}}{\text{length}}$ and becomes smaller as the wave becomes larger. In the table following, and on Plate xxxvi., data are given illustrating the relation between these properties. It is interesting to note that in the case of small waves the rate of travel is much greater than that of the exciting wind. At first glance this seems paradoxical, but on consideration it is seen that the water forming the waves is practically stationary relative to the wind which gives its impetus to each wave surface as it rises.

TABLE SHOWING PROPERTIES OF STEADY WAVES.

Wind velocity, miles per hour.	Fetch, miles.	Wave length, feet.	Wave height, feet.	Wave speed, miles per hour.	Frequency. Waves per minute.
v.	3·78 v.	10 v.	$\frac{1}{2}$ v.	$4·9\sqrt{v.}$	$\frac{43·1}{\sqrt{v.}}$
0·2	0·6	1·7	$\frac{1}{12}$	2·6	134·7
1	3 8	10	$\frac{1}{2}$	4·9	43·1
2	7·6	20	1	6·9	30·3
10	38	100	5	15·5	13·6
20	76	200	10	21·9	9·6
30	114	300	15	26·8	7·8
40	152	400	20	31·0	6·8
50	189	500	25	34·6	6·1
60	227	600	30	38·0	5·6
70	265	700	35	40·9	5·2
80	303	800	40	43·8	4·8
90	340	900	45	46·5	4·5

DATA FOR CALCULATION OF PROPERTIES OF WAVES.

Length = 20 × height.
Wind velocity (miles per hour) = 2 × height in feet.
Fetch = 2000 × length.
Fetch in miles = 0·3788 × length in feet.
Wave speed in miles = $1·55 \times \sqrt{\text{length in feet.}}$

$$\text{Frequency} = \frac{\text{Wave speed.}}{\text{Wave length.}}$$

When watching waves beating on the ocean beach most people have noticed that at more or less frequent intervals a wave considerably larger than the others will occur. The steady waves may be due to wind, while the larger ones of longer period may arise from one or other of different causes, but we have in such a case merely to do with two different wave-systems acting simultaneously. Each series has its own properties, and the larger waves arrive at their proper intervals quite independently of the smaller.

Next to waves quite the most striking physical phenomenon connected with the sea is that of tides. A tide is by no means the simple movement of the water which might be supposed. There are many complicating influences besides the ever-varying incidences of the attraction of moon and sun, and the tide is really a summation of all these. I will not, however, deal particularly with the problem of tidal analysis, but I desire more especially to speak of one of the more important results of the action of tides upon the fate of the world. The effects of the tides on terrestrial motion are of the most profound importance, for the result of their action is, through friction, to slow down the rate of rotation of the earth, and thus to lengthen our day. So great, however, is the energy by virtue of which the earth is spinning on its axis, that the enormous force with which the tides tend to retard it is only competent in 1,000 years to increase the length of our day by a small fraction of a second. As Sir Robert Ball has very truly said, however, "what may be a very small matter in one thousand years can become a very large one in many millions of years." This will help us in our attempts to form some mental conception of the expanse of time which is involved in the history of the world. There was a time when our earth whirled round its axis in some three hours, that being the length of the day, and we calculate that it was somewhere about this period that the moon was thrown off. Since that unspeakably remote period the moon has been steadily at work acting as a break on the world, and at the same time has been continually increasing her own distance from us. In obedience to a well defined law, the moon is ceaselessly withdrawing from the earth, her orbit being really an ever expanding spiral. This is a necessary result of tidal action, and the distance of the moon from us is rigidly determined by the rate at which the world revolves. Let us think of the æons of millions of years which have elapsed since the moon began at the average rate of a small fraction of a second in a thousand years to increase the length of the terrestrial day by some 21 hours! And this action must go on until our day becomes longer and longer, until it stretches out to a month, and the moon will then face the earth continuously at one spot, and lunar tides will cease. The moon and the earth will then be each revolving around its axis in equal times, and so must face one another in one position. The tidal influence of the sun will still go on, and the ultimate result will be that in the infinitely remote future the period of the earth's revolution will stretch out to a year, and the earth will then face the sun as the moon now faces the earth. It will then be perpetual day on the side of the earth which is turned to the sun, and perpetual night on that which is turned away. That is assuming that the sun is still capable of giving off heat and light. And all this will have been due to the tides; so we see how profound are the results induced by the physical properties of the ocean. The fact of the absence of tides in enclosed seas of even considerable size, such, for example, as the Caspian and Black Seas, and the very insignificant tides experienced in the Mediterranean, are due to the area of these not being sufficiently great for the moon to be able to raise a tide; the moon pulls such areas of water practically as a whole.

Considering the enormous effect of the moon when acting on a large surface area, it is not a little surprising, at first sight, to find that appliances of the utmost delicacy are required to measure, or even to demonstrate, our satellite's attraction. The amount of this attraction can be calculated readily enough, but to show its existence experimentally is a very difficult matter. This was done by Professor G. H. Darwin at Cambridge, by suspending, with most elaborate precautions, a mass of copper weighing several pounds, on a long wire, in such a position that when the moon was at right angles to the weight, and therefore pulling horizontally, the minute displacement could be measured by means of a tiny mirror placed on a wire torsion frame attached to the weight and reflecting a beam of light on to a scale.

It is from the evaporation of the water of the ocean through the agency of the sun's heat that is derived by far the greater bulk of the rain and snow which fall on the globe. When water is evaporated a large amount of heat is rendered latent and locked up in the vapour, to be given out again on condensation. Heat is measured in terms of the amount required to warm water. The quantity of heat which will warm 1 lb. of water 1° F. is termed a heat unit, and is the British thermal standard. Now water warmed from ordinary temperature, say 60° F., to boiling point, which is 212° F., requires just 152 heat units per lb. When a pound of water is evaporated, however, a very much larger quantity of heat is necessary, for it requires 966 units to merely evaporate that amount without further increasing its temperature. This means that just about $6\frac{1}{3}$ times the amount of heat is required to change water into vapour as would suffice to raise it from the ordinary temperature to boiling point. It does not matter whether the water is boiling or not, its evaporation at ordinary or any temperature requires practically the same amount of heat, and the vapour on condensing gives up the whole of this. As perhaps giving a better idea of the significance of these figures, it may be mentioned in passing that the quantity of heat required to evaporate one pound of water represents energy equivalent to the force required to lift $3\frac{1}{3}$ tons 100 feet above the earth's surface. Every pound of water which falls as rain has therefore seized on and transported to the area in which the rain is condensed sufficient heat to elevate $3\frac{1}{3}$ tons 100 feet. The imagination fails to properly grasp how enormous must be the amount of heat required to vapourise the great volume of water daily evaporated from the ocean. The transference of such quantities of the sun's heat from the surface of the ocean where it is received to the places where the clouds are formed has a very great effect on climate; in fact we may safely say that the ocean forms the great storehouse of heat for the habitable part of the globe's surface, and that, but for the sea and the phenomena of evaporation and rain, the climatic conditions would be such that the earth would be uninhabitable to creatures constituted as we are. But for the equalising effect of the great ocean surfaces and the evaporation therefrom, with the consequent transport of heat, together with the blanketing effect of the clouds, we should have, over the greater part of the earth's surface, intense heat by day and unendurable cold as soon as the sun had set.

Another matter of immense importance in the relationship of the ocean and atmosphere is the regulating effect which is exercised by the former on the carbon dioxide content of the latter. This question has been studied by Dr. A. Krogh of Copenhagen.* Briefly put, the conclusions arrived at may be stated thus. The atmosphere over the southern hemisphere, where ocean surface greatly preponderates, contains 0·026 per cent. of carbon dioxide ; over the northern oceans the proportion is 0·029 per cent., while in Central Europe it rises to 0·033 per cent. The total amount of carbon dioxide contained in the ocean has been calculated to be about $6{\cdot}55 \times 10^{16}$ kilograms, existing mainly in readily dissociated salts, while the atmosphere holds about one twenty-seventh of this amount. Any increase in the proportion of carbon dioxide in the atmosphere is checked by the action of the ocean water, which immediately absorbs the greater bulk of it. To increase the proportion of carbon dioxide in the atmosphere from the present 0·03 per cent. to 0·04 per cent. would require in the first place an addition of one-third of the total existing amount, which in itself is an enormous quantity; and further, in order to bring the ocean into equilibrium with the air so as to enable the latter to retain the increase, about twice the present amount in the air would have to be provided. Dr. Krogh considers from this standpoint the effect of the world's consumption of coal, which is estimated to pour into the atmosphere annually about one-thousandth of its present percentage proportion of carbon dioxide. This means that assuming the coal supply to last and consumption to continue at present rate,

* Meddelelser om Gronland, xxvi. 333-409; Journ. Chem. Soc. London, lxxxviii., 11, 26 ; Compt. rend. 139, 896-8; Nature, lxxi. 283.

in one thousand years the proportion of carbon dioxide in the air would, apart from the regulating effect of the sea, be doubled, and the percentage would then be 0·06, a proportion which it is considered would render the atmosphere almost unfit for continued respiration. As the result of direct experiment it is concluded that before the proportion of carbon dioxide rose to 0·031 per cent. the sea would absorb it as fast as it was produced, "and, owing to the large volume required to bring the ocean into equilibrium with the air, it is probable that at the expiration of the thousand years the proportion of carbon dioxide in the air would not be more than 3·5 vols. per 10,000," which is 0·035 per cent. So far as the products of the life and decay of living organisms are concerned, it may be safely concluded that by these agencies there is returned to the air the same amount of carbon dioxide as is withdrawn, for the sum total of organic life remains practically unaltered from year to year.

In considering the influence of atmospheric constituents on living organisms it is interesting to note some observations made by Dr. A. Marcacci,* who has shown that, when the nitrogen in the air is replaced by hydrogen, animals placed therein soon die, not from any poisonous effect of the hydrogen, but simply because of the much greater thermal conductivity of that gas. The death of the animals is in fact due to the increased loss of heat, which the organism is unable to maintain, though the effort to do so is evidenced by a greatly increased absorption of oxygen and evolution of carbon dioxide.

Vast quantities of water are condensed around the cold polar regions of the earth, giving rise to the accumulations of ice which permanently cap the poles. The opinion was at one time widely held that there must be prodigious aggregations of ice at the poles, because where the ice never melts there seemed no limit to the possibilities of its accumulation, and it was even considered probable that a world-wide deluge might be caused when the mountain of ice became so great as to overbalance, and in falling

* Nature, June 30, 1904, 201.

into the ocean set up a huge wave of displacement which would sweep to its furthest limits. Happily, however, for the stability of the earth, there is a property of ice which renders this impossible. If we take a piece of ice and submit it to pressure it becomes plastic and moulds itself exactly to the shape of the vessel in which it is contained, and if the pressure is sufficiently great the ice becomes liquefied. When ice is piled on ice until a sufficient pressure is attained, the bottom ice spreads out like so much pitch, and even the pressure of a very moderate height is ample to produce this effect on unrestrained ice. Lord Kelvin has shown that, under the conditions ruling in the great south polar continent, it is improbable that ice can be so restrained as to attain a greater thickness than 2,000 or 3,000 feet. This when melted is equivalent to a depth of 1,600 to 2,400 feet of water. Free or unrestrained ice, whether resting on land or floating on water cannot permanently retain any given thickness; owing to its plasticity it will slowly but surely spread out until stopped by barriers or melted. It is to this plasticity that are due the enormous ice cliffs so graphically illustrated in the account of the recent National Antarctic Expedition,* for the great ice mass merely flows under the pressure of its own weight until it reaches the sea where it floats, while portions are broken off and drift away as icebergs. The ice barrier is, in fact, the continually renewed face of the ice mass which is ceaselessly moving outwards in obedience to the pressure of the constant accumulation behind.

It is quite possible that there may at various periods in geological time have been considerable fluctuations in the quantity of ice accumulated at the poles, and it will be interesting to consider very briefly what would be the effect on the ocean level of the withdrawal of definite quantities of water to be stored at the poles as ice, or conversely what would be the result of the addition to the sea of the masses of water set free by the melting of given heights of polar ice.

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* The Voyage of the Discovery: Capt. R. F. Scott, 1905.

Taking Murray's estimate of the size of the south polar continent as being about one-fortieth of the total area of the earth's surface, Lord Kelvin calculates that a layer of ice 1,200 feet in thickness covering this area—equivalent to a depth of 1,000 feet of water—would, if melted and added to the ocean, suffice to raise its level all over the globe by about 25 feet. In like manner a withdrawal of the same amount of water would cause a universal lowering of the ocean level by 25 feet. Were there a similar accumulation at the Arctic pole, the total variation in ocean level would be 50 feet. There does not seem to be any other way in which serious quantities of water could be taken from the ocean or added thereto. Now Professor Suess in his great work 'Das Antlitz der Erde,' published in 1884, an English translation of which by Dr. Hertha Sollas and Professor W. J. Sollas was brought out so recently as 1904,* combats altogether the theory of the rise of land masses. Suess considers that all phenomena indicating a lowering of ocean level relative to land are due to real alterations in the water level, and not to any rising of the land. He concludes that any plateau consisting of marine sedimentary rocks now existing at an altitude above sea-level, indicates vertical alteration in the level of the water at least equal to such altitude. We have seen that, assuming an Arctic area available for storage of ice equal to that existing in the Antarctic, an accumulation of 1,200 feet of ice over both regions would be competent to produce a universal lowering of about 50 feet in the ocean level, and that the maximum height to which ice could be piled under polar conditions is considered by Lord Kelvin to be about 3,000 feet. From these figures it is easy to calculate that, given a uniform accumulation of ice to a height of 3,000 feet over both polar regions, the difference in ocean level would only be about 125 feet, while we have innumerable large areas of marine sedimentary rocks at enormously greater altitudes than this. While it thus seems evident that the greatest possible accumulation of ice in the polar

* Reviewed by J.W.G. in 'Nature,' June 29, 1905, p. 193.

regions is not sufficient to account for the difference between the existing sea-level and the horizon of very many deposits of marine strata, it is quite probable, as has been already indicated, that considerable fluctuations in the quantity of ice stored at the poles may have taken place, and that some of the minor mutations in ocean level, which have left records behind, may have been due to this cause.

The existence of fossils of various kinds *in situ* in the polar regions proves that at some period in the past the climate in these places must have been very much warmer than is now the case. Now there are very great physical difficulties in the way of any change in the position of the world relative to the sun, which would cause any material alteration in the situation of the polar ice-caps. In fact, short of a catastrophaic occurrence quite out of the orderly sequence of events, there does not seem any possibility of such a change taking place. The total variation of polar position relative to the sun, caused by the precession of the equinoxes—an event occupying about 26,000 years—is much too small to have so great an effect, even when the period of greatest displacement of the earth's poles is made to coincide with the most favourable position of the earth in its orbit, relative to the sun. By a catastrophaic occurrence is to be understood such an event as the impact of a gigantic meteorite, sufficient to upset the equilibrium of the earth and materially alter its centre of gravity. While it is by no means impossible or even improbable that such an event may have taken place, we have no direct evidence thereof, and there is little doubt that collision with a body sufficiently large to induce so great a change would result in the liberation of an amount of heat that would instantly destroy all life on the globe. Certainly there are in particular spots on the earth's surface great masses of iron, which are usually considered to be of meteoric origin, but it may well be doubted if the impact of these would be sufficiently severe to produce the change in position in question. It has been suggested that, as the world in the first instance gradually cooled from its pristine molten condition, the equatorial regions must have been intolerably hot at a period when the poles enjoyed quite a moderate climate, or even one comparable with present-day tropical conditions. It would thus come about that the polar regions would be the first portion of the earth's surface to become inhabitable to living organisms, and so in the seas around a polar continent may have originated the life now common to the whole world. The fossil remains, however, which are found in the polar regions, are not those of such organisms as investigation elsewhere has shown to have existed at early geological periods, while in the Arctic region, at any rate, remains of trees of modern age have been found apparently *in situ*.

The subject is one of great difficulty and obscurity, but so far as I understand the evidence, the most probable cause of a material change in the rigour of the polar climate is alteration in the land level. In different tropical and sub-tropical regions of the earth there is unmistakable evidence of glacial action, where, I take it, it is inadmissible to suppose that under existing conditions of land level the climate can ever have been frigid. We seem forced, then, to accept the hypothesis that, when glaciation occurred, the land surfaces involved were at a much greater elevation than now, and, in fact, constituted true alpine areas.

Let us for a moment apply this principle to the polar regions. Were the entire polar areas free from land, and covered by open sea having full communication with the tropical oceans, the result would be a flow of warm water from the tropics across the poles, and a profound change in the prevailing temperature, a modification much greater indeed than that produced in Northern Europe by the influence of the Gulf Stream. Where there is no land neither ice nor snow can accumulate, and given limited areas of land forming islands studding the polar seas, the climate on these would, during the summer, be quite comparable with that of temperate regions, while the winter would be much less rigorous than under existing conditions. The blanketing effect of the dense clouds which would be continually hanging over the poles, together with the heat liberated by their condensation from vapour, would have much to do with the production of an equable climate. The germ of this theory was, I believe, first suggested by Sir Charles Lyell, and afterwards developed by Lord Kelvin, and it seems to offer a very acceptable solution of the problem. When we have in India and elsewhere evidences of glacial action necessitating enormous change in land horizon, it is reasonable to admit the very much smaller rise or fall required to produce the requisite climatic changes at the poles.

I will conclude with a favourite sentiment of a revered former occupant of this honourable chair—

"FLOREAT SOCIETAS LINNEANA!"

The Hon. Treasurer presented the balance sheet for the year 1905, which was received and adopted. The Society's income for the year ended December 31st, 1905, was £1,098 13s. 4d.; the expenditure £957 6s. 3d.; with a debit balance of £63 2s. 6d. from the previous year, leaving a credit balance of £78 4s. 7d. The income of the Bacteriological Department was £540 13s. 4d.; and the expenditure £496 0s. 11d.; with a credit balance of £193 15s. 1d. from the previous year, leaving a credit balance of £238 7s. 6d. In regard to the Macleay Fellowships' Account, the income was £1,349 8s. 6d.; and the expenditure £300 10s. 6d.; leaving a credit balance of £1,048 18s. 6d. to be carried to Capital Account.

After a ballot had been taken to fill vacancies in the Council, the President declared the following elections for the current Session to have been duly made:—

PRESIDENT: Thomas Steel, F.C.S., F.L.S.

MEMBERS OF COUNCIL (to fill six vacancies): R. T. Baker, F.L.S., W. W. Froggatt, F.L.S., C. Hedley, F.L.S., A. H. S. Lucas, M.A., B.Sc., and Fred. Turner, F.L.S., F.R.H.S.

AUDITORS: Duncan Carson, E. G. W. Palmer, J.P.